

Historical tsunamis in the Sea of Marmara

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Abstract. The fact that a tsunami might occur as the consequence of a probable large-scale earthquake in the region is a popular subject. A recent coseismic tsunami in Izmit Bay caused by the Kocaeli earthquake on 17 August 1999 has once more emphasized this fact and how the knowledge of historical tsunamis is important. When the tsunamigenic potential of the Sea of Marmara is assessed, over 40 tsunamis have taken place during the course of an observational period of about 2000 years. The areas in which such waves have concentrated are Izmit Bay, Istanbul coasts, Gemlik Bay, Kapidag Peninsula, and Gelibolu coasts. The tsunami created by the Kocaeli earthquake in the Izmit Bay is the last example of tsunamis in Marmara. A study of the last and previous tsunamis in detail will shed some light on the subject.

1. Introduction

The Sea of Marmara is a complicated tectonic basin positioned in the western part of the right lateral strike-slip North Anatolia fault (NAF) zone. The westward escape of the Anatolian plate along the NAF zone, with an annual slip rate of about 25 mm (Stein *et al.*, 1996; Straub and Kahle, 1997), causes earthquakes in and around the Sea of Marmara. The NAF zone branches out west of 31°E longitude (Barka and Kadinsky-Cade, 1988). The middle branch follows along the southern coasts of the Sea of Marmara, while the northern branch runs within Izmit Bay and the deep Marmara troughs (Fig. 1a).

Its shelves are widely (57%) distributed and bounded by the steep slopes of three large (and two small perched) depressions. Deep troughs which are more than 1100 m are separated from each other with saddles several hundred meters high.

Recent studies indicated that the average deposition rate of the soft

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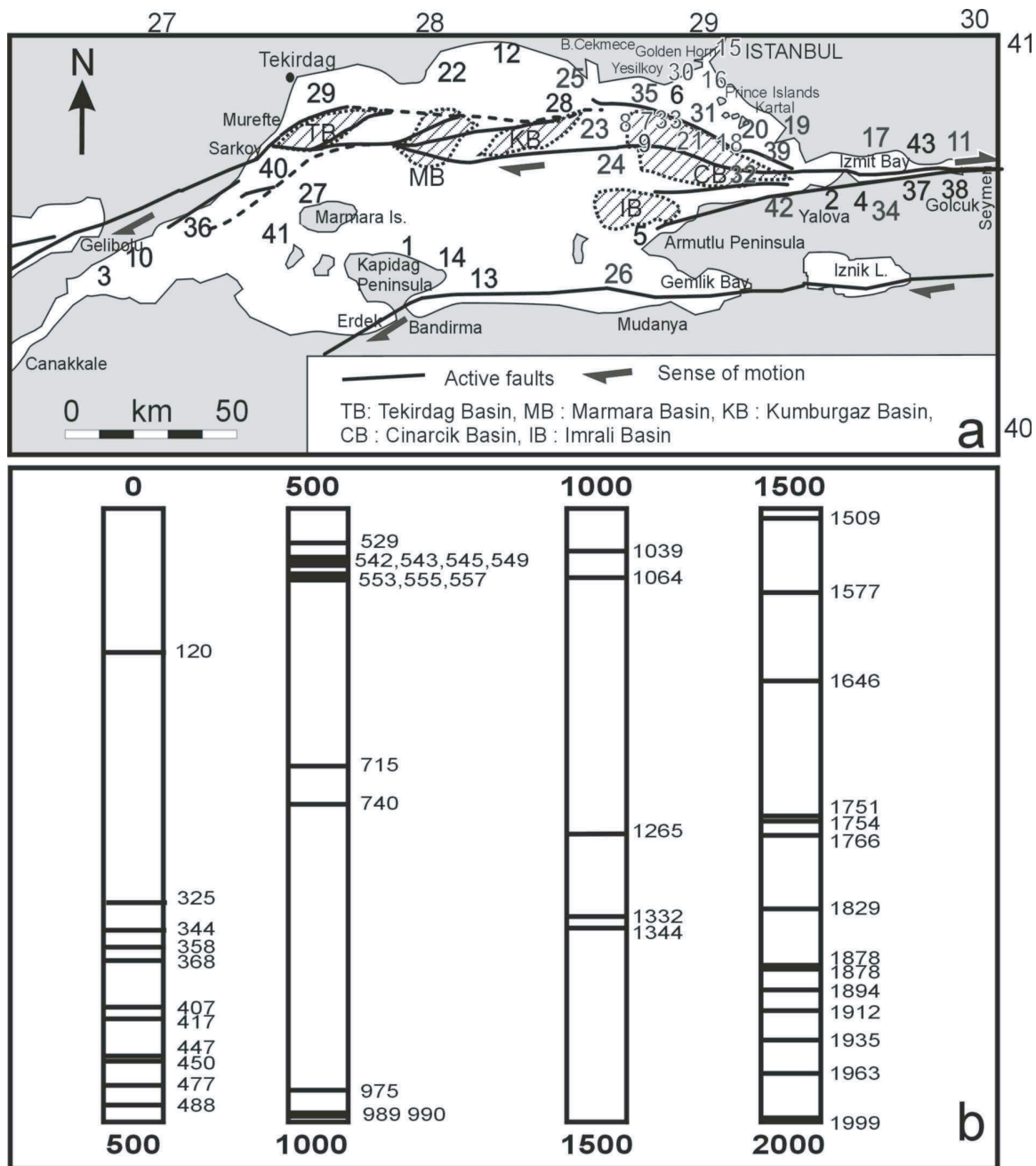


Figure 1: (a) Historical tsunamis in ascending order (120 to 1999 AD). Events superimposed on deep troughs and active faults in the sea of Marmara (Yaltirak *et al.*, 2000). (b) Temporal distribution of historical tsunamis in the sea of Marmara.

muddy sediments in depressions is higher. The reason is probably due to submarine landslides and turbidites. In particular, synthetic faults of the NAF's northern branch which are integrated with the slopes (Alpar and Yaltirak, 2000a) may cause significant submarine landslides. Wave movements caused by such submarine landslides affect the coastal areas.

An earthquake is now more likely to occur in the Sea of Marmara since the Kocaeli (17 August 1999) and Duzce (12 November 1999) earthquakes, both of which occurred on the NAF's northern branch. There are arguments for the location and magnitude of the expected earthquake. Against some proposals about an earthquake of magnitude 8 due to a curved buried master fault under the Sea of Marmara, Hubert-Ferrari *et al.* (2000) suggested that one or two earthquakes are likely to occur during the next 30 years with magnitudes of 7.2–7.4. Parsons *et al.* (2000) has given the probability of occurrence of an earthquake in Istanbul and the environs during the next 30 years as $62 \pm 15\%$.

Another subject at issue is whether an earthquake likely to occur in the Sea of Marmara would cause a tsunami or not. It is known that over 90 tsunamis have occurred in the four seas bordering Turkey's 8300-km long coasts over an observational period of 3000 years. One third of such waves have taken place in the Sea of Marmara (Altinok and Ersoy, 2000; Altinok, 2000). Tsunamis that occurred from 120 to 1999 A.D. are numbered in order of historical occurrence (Fig. 1a).

2. Material and Method

In this study, sources published in Turkish and western languages have been used first. Effort has been made to have access to the original sources thereof as far as possible and, therefore, the Ottoman Archives, church manuscripts, old newspapers, and magazines at various libraries have been searched. Translation of the sources written in the Ottoman language found in the Ottoman archives and old newspapers involve a troublesome effort because of language variations throughout the centuries. Besides the archives and libraries, such printed matter as novels, diaries, and other sources of documentary character have also been traced. These efforts are still under way.

3. Some Effective Tsunamis in the Sea of Marmara

Between 2100 BC and 1900 AD, more than 300 historical earthquakes and over 40 tsunamis have taken place in the Sea of Marmara between 120 and 1999 A.D. (Figs. 1a and 1b). Even though there is some disagreement in dates (Altinok and Ersoy, 2000), the most acknowledged of them are given below in detail to the extent that they could be traced on the basis of available sources.

- 120/128: The earthquake which affected the areas of Kapidag Penin-

sula, Iznik, and Izmit created a tsunami along the shores of Kapidag Peninsula (Guidoboni *et al.*, 1994).

- 24 August 358: With the earthquake in the Marmara, a tsunami was observed in the city of Izmit (Guidoboni *et al.*, 1994; Ambraseys and Finkel, 1991).
- 26 January 447: Combined with the earthquake affecting the cities of Istanbul and Izmit, dead fish were found on land and ships were grounded due to a receding of the sea in the town of Izmit (Guidoboni *et al.*, 1994; Ambraseys and Finkel, 1991; Soloviev *et al.*, 2000).
- 24/25/26 September 477/480: With the earthquake which affected Canakkale, Istanbul, Izmit, Gelibolu, and Bozcaada, a tsunami occurred in Istanbul and damaged coastal areas (Guidoboni *et al.*, 1994; Ambraseys and Finkel, 1991).
- August 545: Occurrence of a tsunami caused many to drown at the Bosphorus (Legofet, 1905).
- 15 August 553: Being effective in Istanbul and Izmit Bay (Soysal *et al.*, 1981), the sea inundated about 2000 m (Soysal, 1985).
- 14 December 557: The earthquake was effective in Istanbul and Izmit Bay (Ambraseys, 1960; Soysal *et al.*, 1981) and the sea inundated about 3000 m (Soysal, 1985).
- October 989: A tsunami occurred during the earthquake in the east of Marmara (Soysal, 1985; Ambraseys and Finkel, 1991).
- 14 October 1344: With the earthquake which affected almost all of the coastal area of the Sea of Marmara, a tsunami occurred (Heck, 1947; Antonopoulos, 1978; Soysal *et al.*, 1981; Soysal, 1985; Papazachos *et al.*, 1986; Soloviev *et al.*, 2000). The sea inundated 2000 m (Ambraseys, 1962; Papadopoulos and Chalkis, 1984).
- 10 September 1509: An earthquake occurred in Istanbul which created a tsunami in Istanbul and the Marmara coasts. The tsunami caused waves that spilled over the city walls of Istanbul (Orgun, 1941). The magnitude of the earthquake was about 8.0 and the wave run-up was above 6.0 m. The walls of Izmit Castle on the shore were damaged beyond repair, the quay walls of the shipyard collapsed and waves flooded the dockyard and the lower districts of the city (Oztin and Bayulke, 1991).
- 5 April 1646: With the earthquake in Istanbul, a tsunami was observed (Heck, 1947; Ambraseys, 1962; Antonopoulos, 1978; Papadopoulos and Chalkis, 1984; Soysal, 1985; Papazachos *et al.*, 1986). Later, Soysal (1985) suggested that this earthquake had occurred on 5 April 1641 and a coseismic tsunami damaged 136 ships.

- September 1754: The tsunami caused by this big earthquake in Izmit Bay inflicted no damage (Ambraseys and Finkel, 1991).
- 22 May 1766: A tsunami occurred with the earthquake (Ambraseys, 1962; Antonopoulos, 1978; Papadopoulos and Chalkis, 1984; Shebalin *et al.*, 1974; Soysal *et al.*, 1981; Soysal, 1985). The tsunami caused considerable damage along the Bosphorus and in the Gulf of Mudanya (Ambraseys and Finkel, 1995).
- 10 July 1894: A tsunami induced by an earthquake was effective in Istanbul. According to Eginitis (1894), the sea receded up to 50 m and then returned back. There was no permanent change to the coastline. The sea rose up and inundated 200 m (Mihailovic, 1927). The tsunami occurred around the Prince Islands and on the coastal area from B. Cekmece to Kartal. The earthquake magnitude was less than 7.0 and the tsunami wave run-up was less than 6.0 m (Oztin and Bayulke, 1991). The sea inundated into the Golden Horn and even the Karakoy and Azapkapi Bridges were under the water (Batur, 1994). Approximately ten minutes before the earthquake, the sea receded at Yesilkoy and, not long after, huge waves attacked the coast and inundated up to 3 rows of houses and even swept off the first row (Batur, 1999). Wave run-up reached its highest level of 2.7 m at Yesilkoy, on the southern coasts of Istanbul (Le Moniteur Oriental, dated 14 July 1894). The sea locally receded up to 15 m off the Prince Islands (Heybeli), then it came back violently, especially in a small bay located south of Heybeli island (Rendelmann, 1895). Most of the rowing boats in the bay sank and a steam ship (Eser-i Cedid) grounded. The sea first receded between B. Cekmece and Yesilkoy, then in 5 min it smashed up, throwing away the boats on land and sweeping off the wharves (Oztin, 1994).
- 9 August 1912: After the Sarkoy-Murefte earthquake with a magnitude of $M_s = 7.4$, the sea along the coast of Tekirdag withdrew for a distance, but returning waves caused no damage (Ambraseys and Finkel, 1987). A tsunami also affected the Istanbul coasts, particularly at Yesilkoy and Bosphorus (Altinok *et al.*, 2001a).
- 4 January 1935: As a result of the earthquake, in the west of Marmara Island (Hayirsiz island), the fog horn building was demolished and the cape part of the island had broken off and fallen into the sea (Son Posta Newspaper, dated 11 January 1935). The rocks at shore had fallen and the sea had risen up (Milliyet Newspaper, dated 12 January 1935).
- 18 September 1963: Following the earthquake ($M_s = 6.3$), shells and shellfish were observed in an E-W direction along the coastline of the Gulf of Mudanya (Ozcicek, 1996–1997). The resulting waves were not too big (Aksam Newspaper, dated 20 September 1963). Waves reached to a height of 1 m and occasionally spilled over the coastal walls in the city of Bandirma (Kuran and Yalciner, 1993).

- The Izmit Bay tsunami of 17 August 1999: The Kocaeli earthquake ($M_w = 7.4$) of 17 August 1999 with a focal depth of 15–17 km created a tsunami in Izmit Bay. The sea receded first in Izmit Bay. Run-ups reached over 2.5 m. The period of waves was less than 1 min. The fault mechanism was dextral with an average slip rate of 2.7 m. Marine seismic data also showed some normal faults related with the master strike-slip fault with releasing bends along the bay (Altinok *et al.*, 1999; Alpar, 1999; Alpar and Yaltirak, 2000b, Yalciner *et al.*, 1999). The reason of subsidence along the southern coasts (Golcuk–Seymen) is the existence of some normal synthetic faults. Although the coastal landslides pose some problems in respect to making exact judgments on the run-ups, especially at the southern coast, there are findings which indicate that a concurrent tsunami developed somewhere near the southern coast (Altinok *et al.*, 2001b). No heavy damage took place on the coasts since the Izmit Bay tsunami was not so great (Yalciner *et al.*, 2000).

4. Conclusion and Suggestions

Historical data reveal that throughout the last 2000 years more than 40 tsunamis have occurred in this sea. The tsunami created by the 17 August 1999 Kocaeli earthquake is the last example of such Marmara tsunamis. These events were clustered in Izmit Bay, the Istanbul shores, Gemlik Bay, Kapidag Peninsula and the Gelibolu shores.

In light of such findings, tsunami probability and its potential effects in Marmara can be identified and described in a more reliable way by improving the available data related to historical tsunamis under the guidance of the data derived from the last Izmit Bay tsunami, searching for the inshore traces of past tsunamis, locating the active faults likely to give rise to an earthquake under the sea of Marmara, and identifying in detail the submarine topography by way of multibeam bathymetric measurements, as well as by making modeling works with the support of all such data.

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